

# Anvil Dissipation and Stratospheric Deuterium

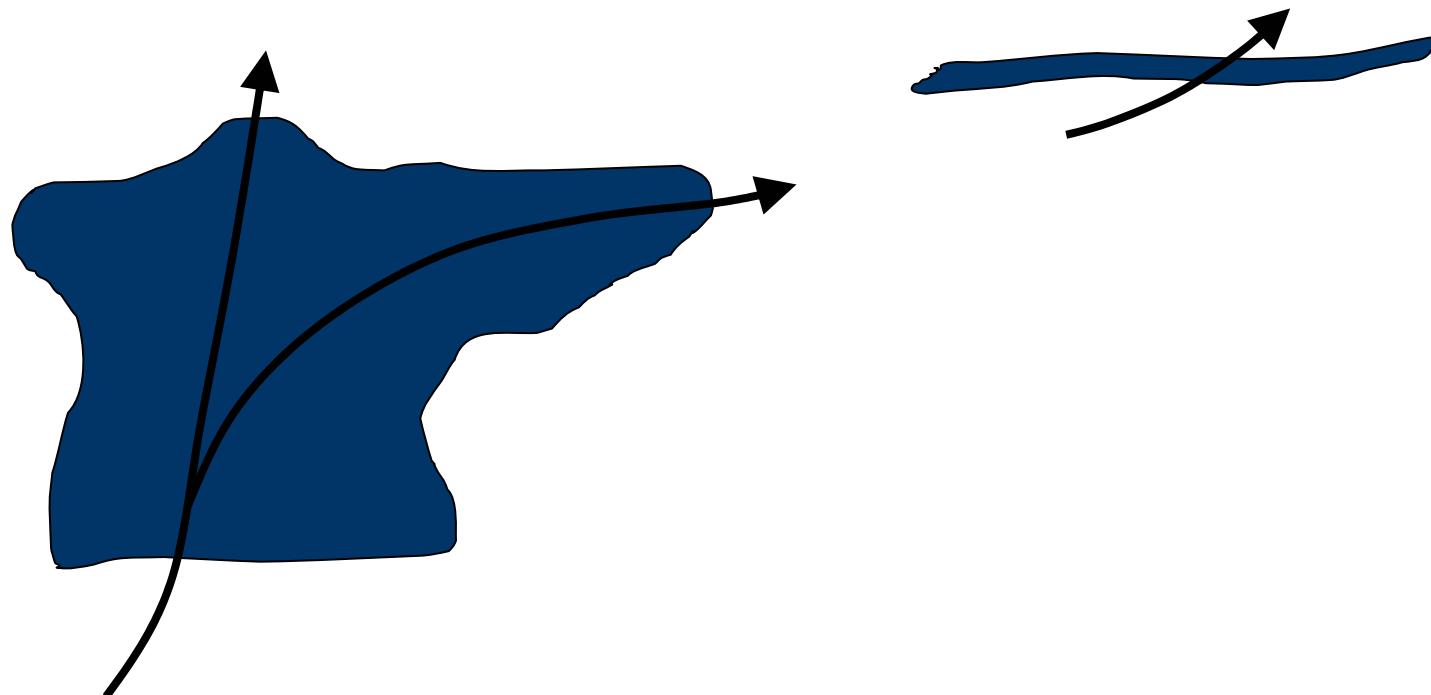
J. A. Smith, A. M. Fridlind, A. S.  
Ackerman, E. J. Jensen, O. B.  
Toon, and D. Wang

# Outline

- Stratospheric Humidity
- Water Isotopomers and Fractionation
- Simulation of Deep Convection
- Simulation of Radiative Ascent
- Conclusions

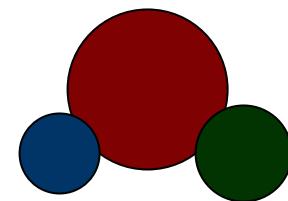
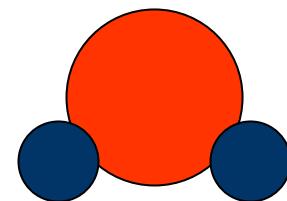
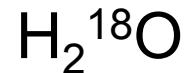
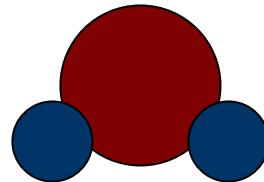
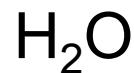
# Stratospheric Humidity

- Humidity of new stratospheric air is  $\sim 4$  ppmv.



- Global warming may perturb stratospheric humidity.

# Water Isotopomers and Fractionation



$$\frac{P^\circ}{P_{\text{H}_2\text{O}}^\circ}$$

1.000

0.991

0.926

$$\alpha$$

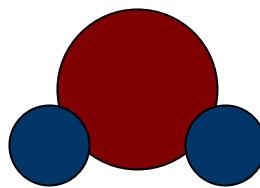
1.000

1.009

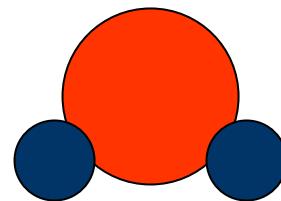
1.08

# Origin of Fractionation Factor, $\alpha$

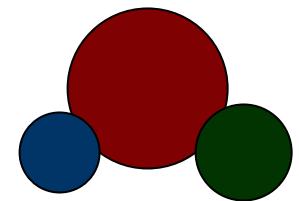
$\text{H}_2\text{O}$



$\text{H}_2^{18}\text{O}$



$\text{HDO}$



Mass (amu)

18

20

19

$\alpha$

1.000

1.009

1.08

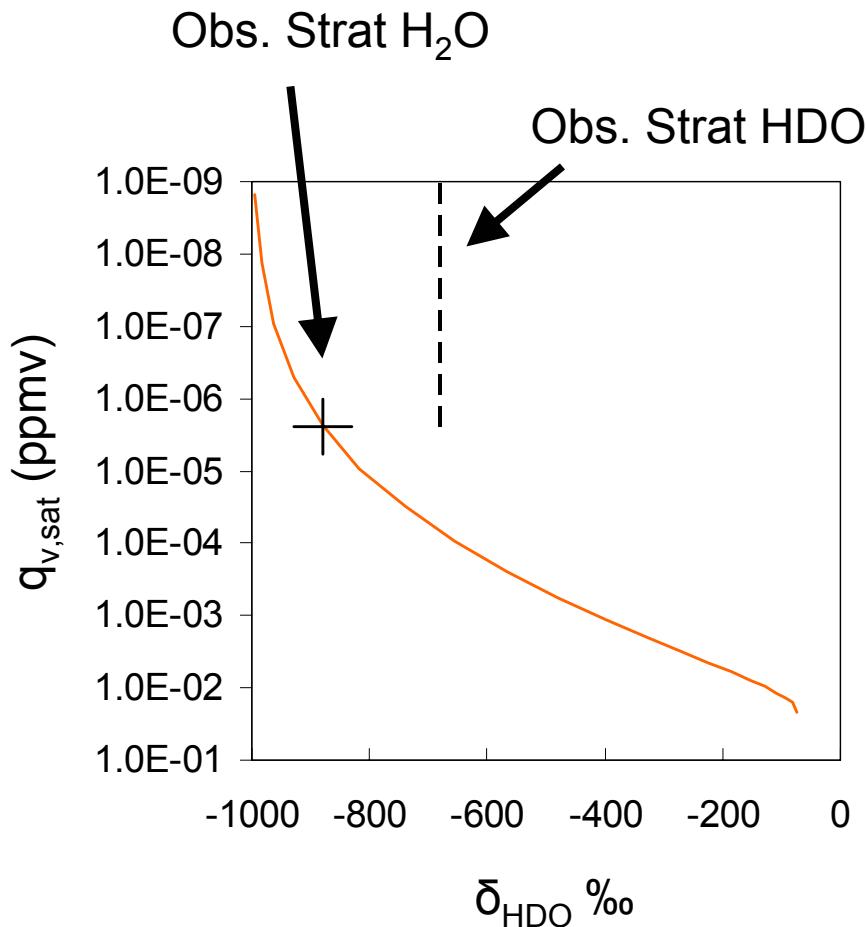
$I_z$  (amu  $\text{\AA}^2$ )

2

2

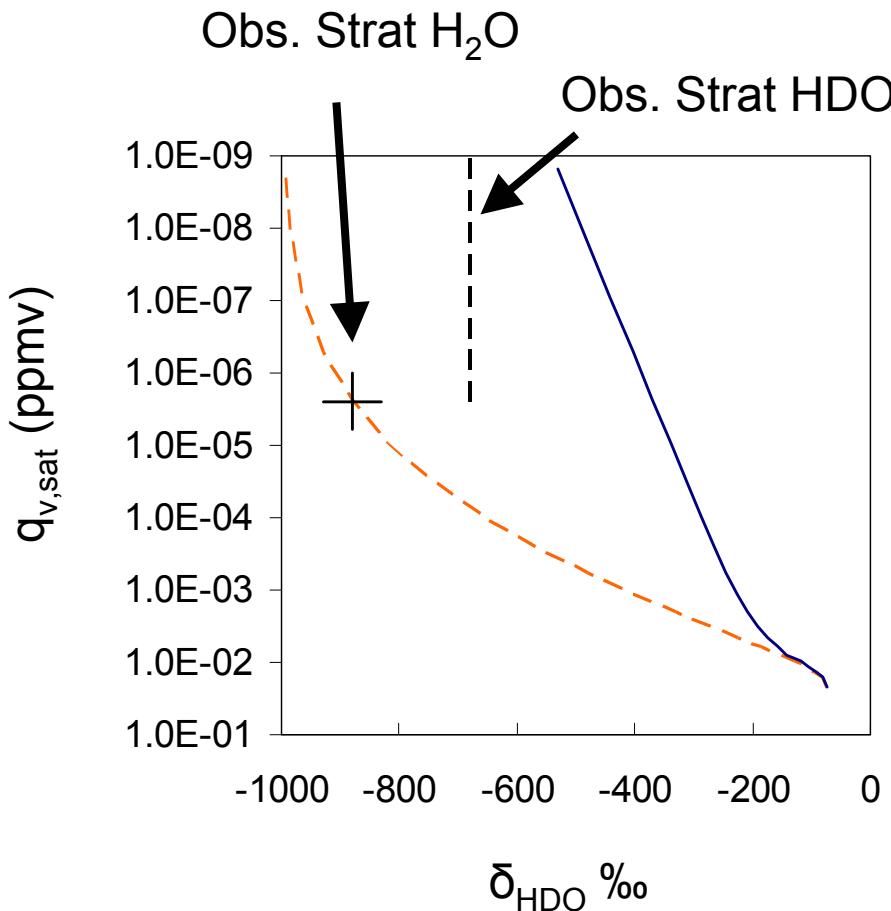
3

# Rayleigh Fractionation



- Lift parcel adiabatically
- Maintain equilibrium isotopic fractionation
- Remove all condensate as precipitation

# Parcel Model



- Lift parcel adiabatically
- Maintain equilibrium isotopic fractionation
- No removal of precipitation

# Deep Convection

- CARMA: mixed-phase, bin-resolving, microphysical model
- DHARMA: 3-D large eddy simulation model

# DHARMA

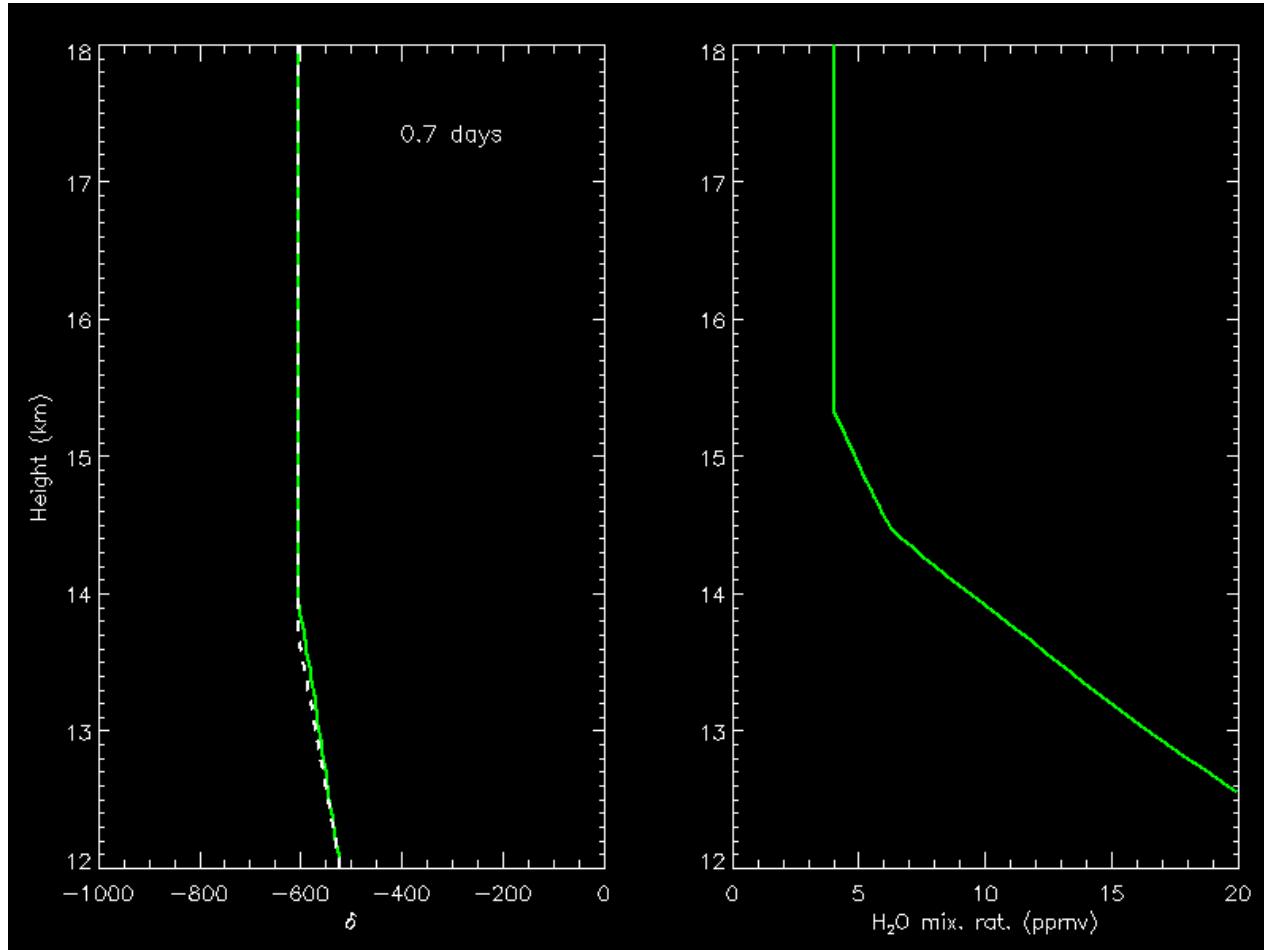
3-D Animation

Cross Sections

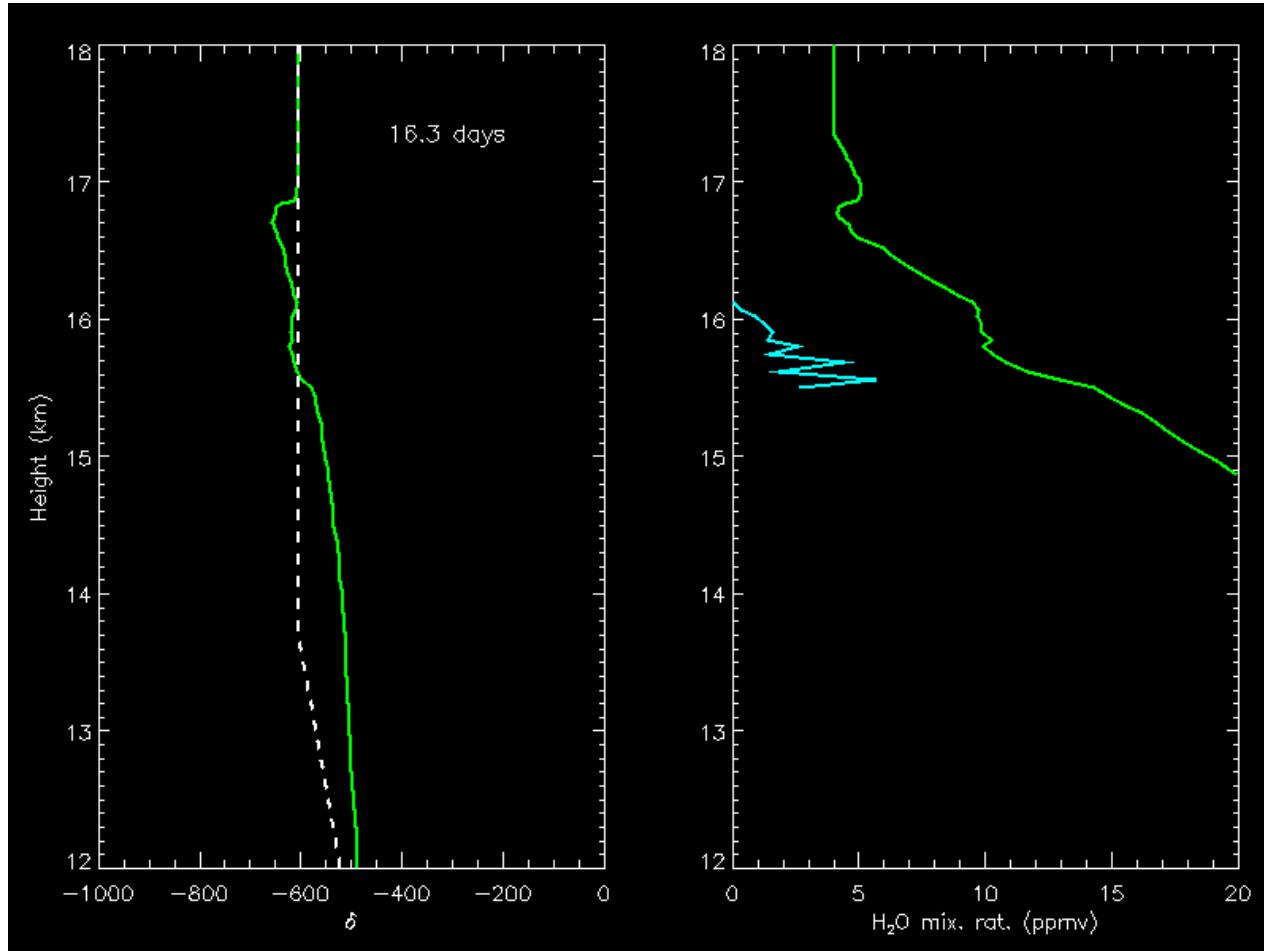
# Radiative Ascent

- Lagrangian particle trajectories through Eulerian atmosphere
- Prescribed uplift velocity
- Equilibrium fractionation

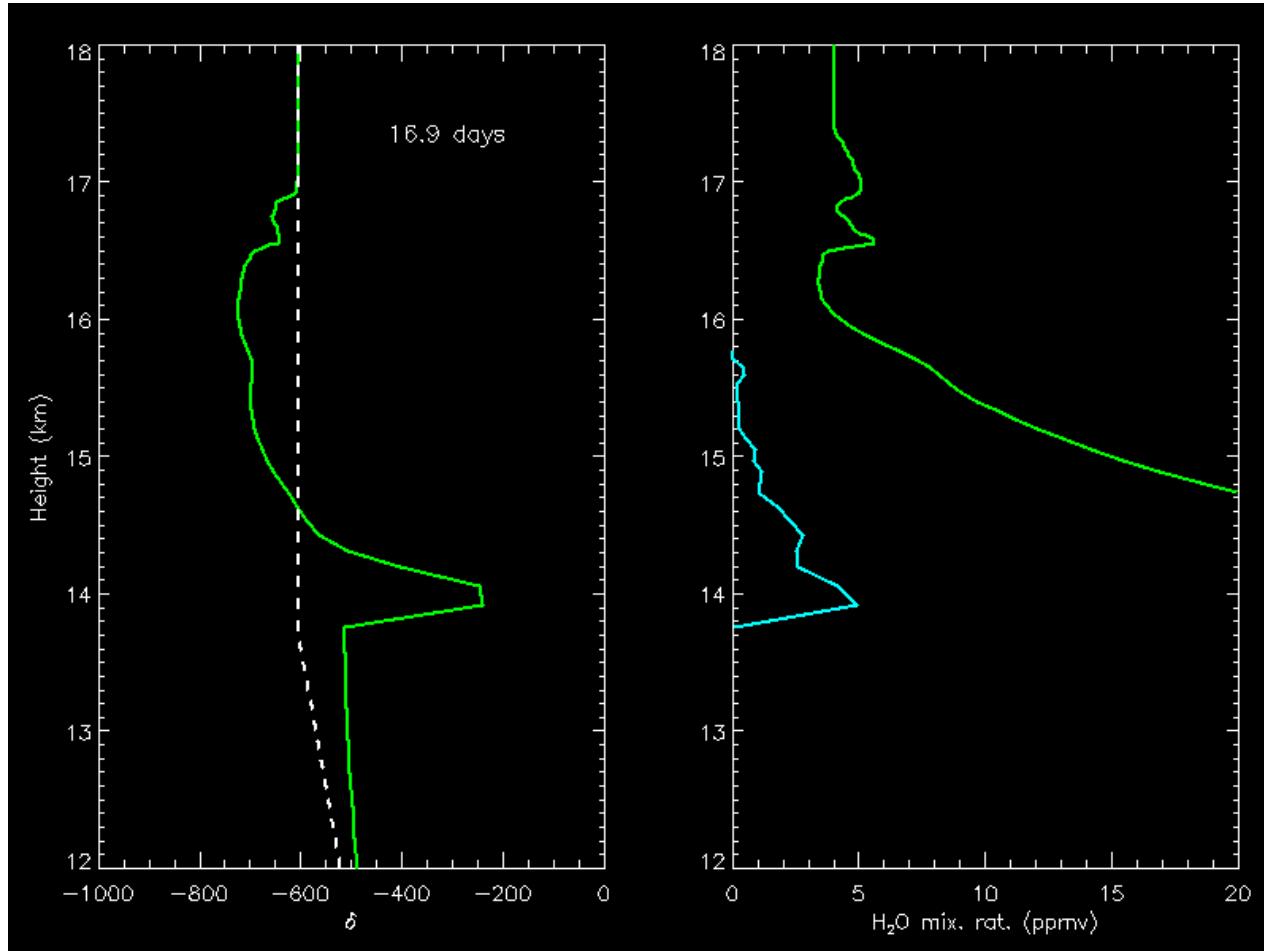
# Slow Ascent through TTL



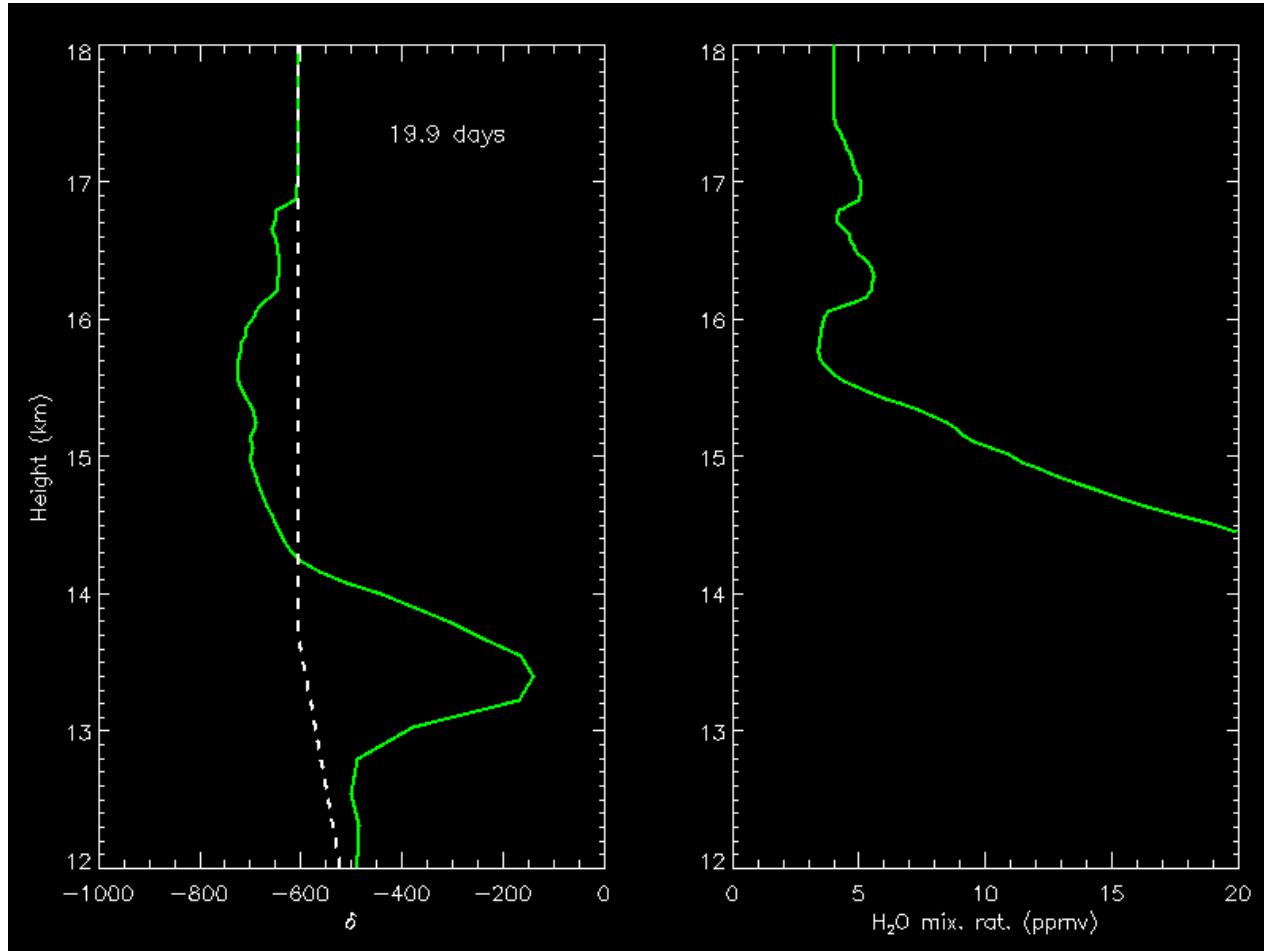
# Slow Ascent through TTL



# Slow Ascent through TTL



# Slow Ascent through TTL



# Conclusions

- Deep convection produces  $\delta_{\text{HDO}}$  of -500‰ in upper troposphere and lower stratosphere
- Slow radiatively driven ascent through a cold trap produces  $\delta_{\text{HDO}}$  of -720‰ in middle stratosphere  
(observed -680‰, Rayleigh -880‰)

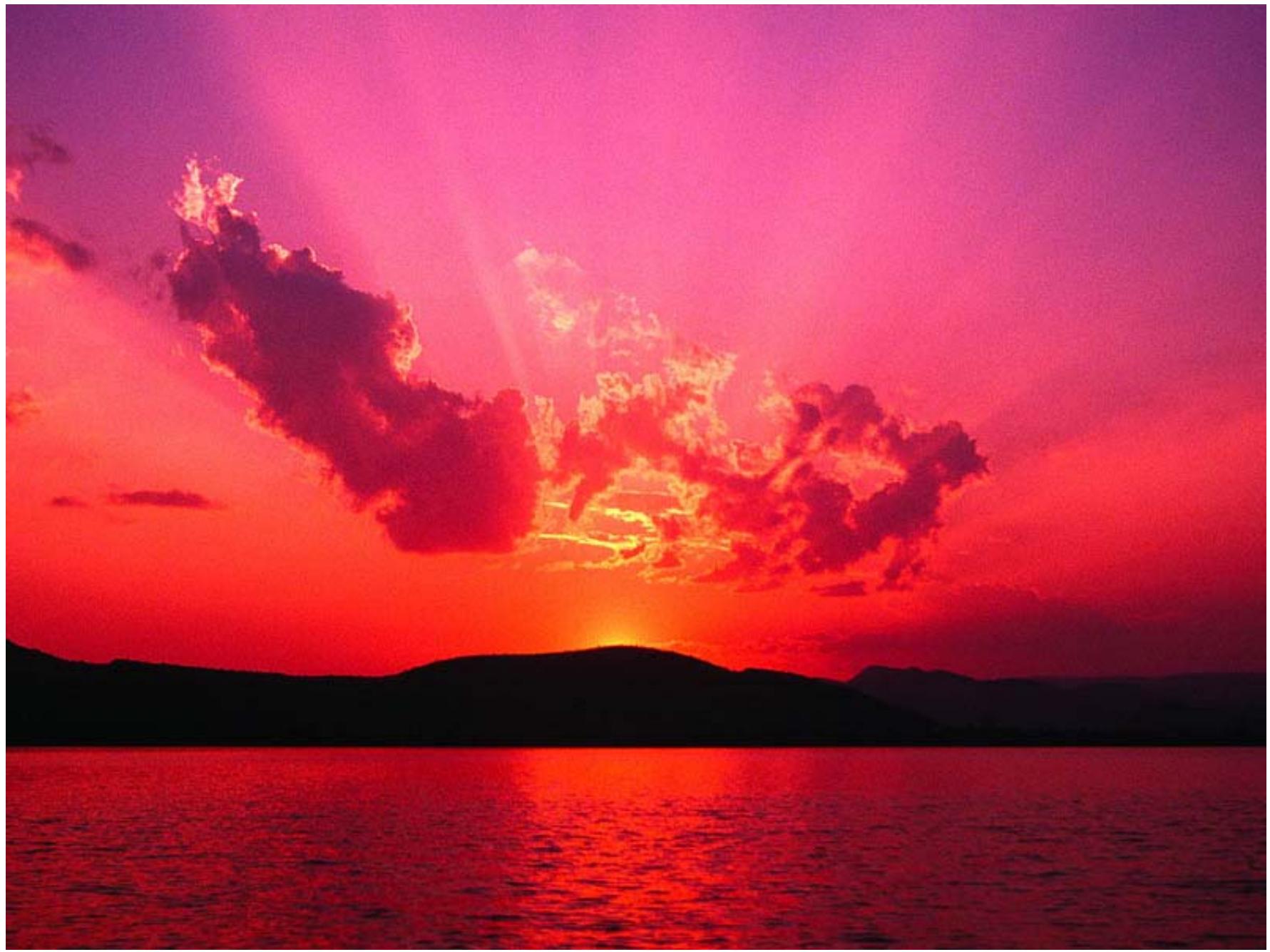
# Acknowledgments

A. Fridlind, A. Ackerman, E. Jensen, B. McKie –  
NASA Ames

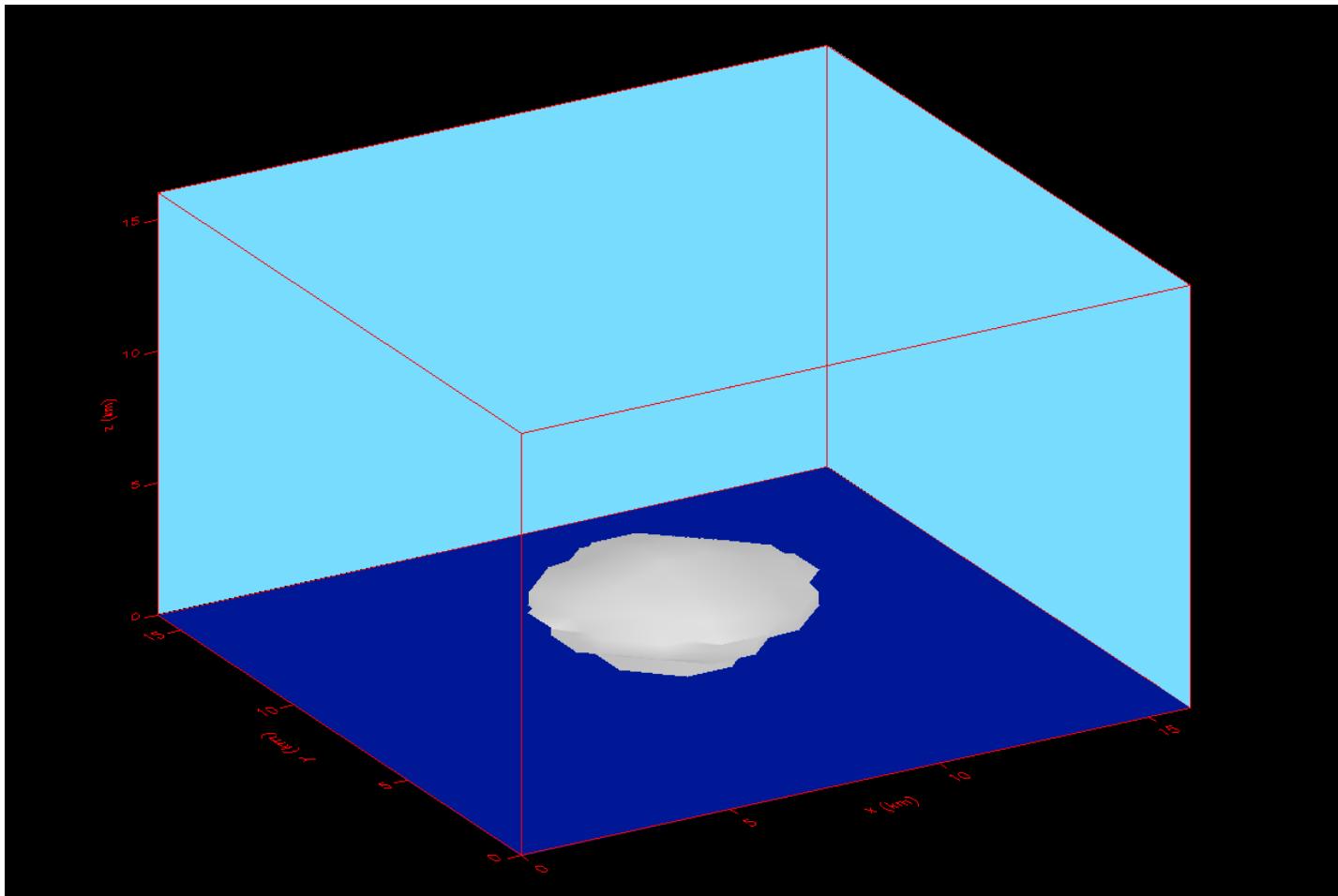
D. Wang – NASA Langley

B. Toon and the Group – CU

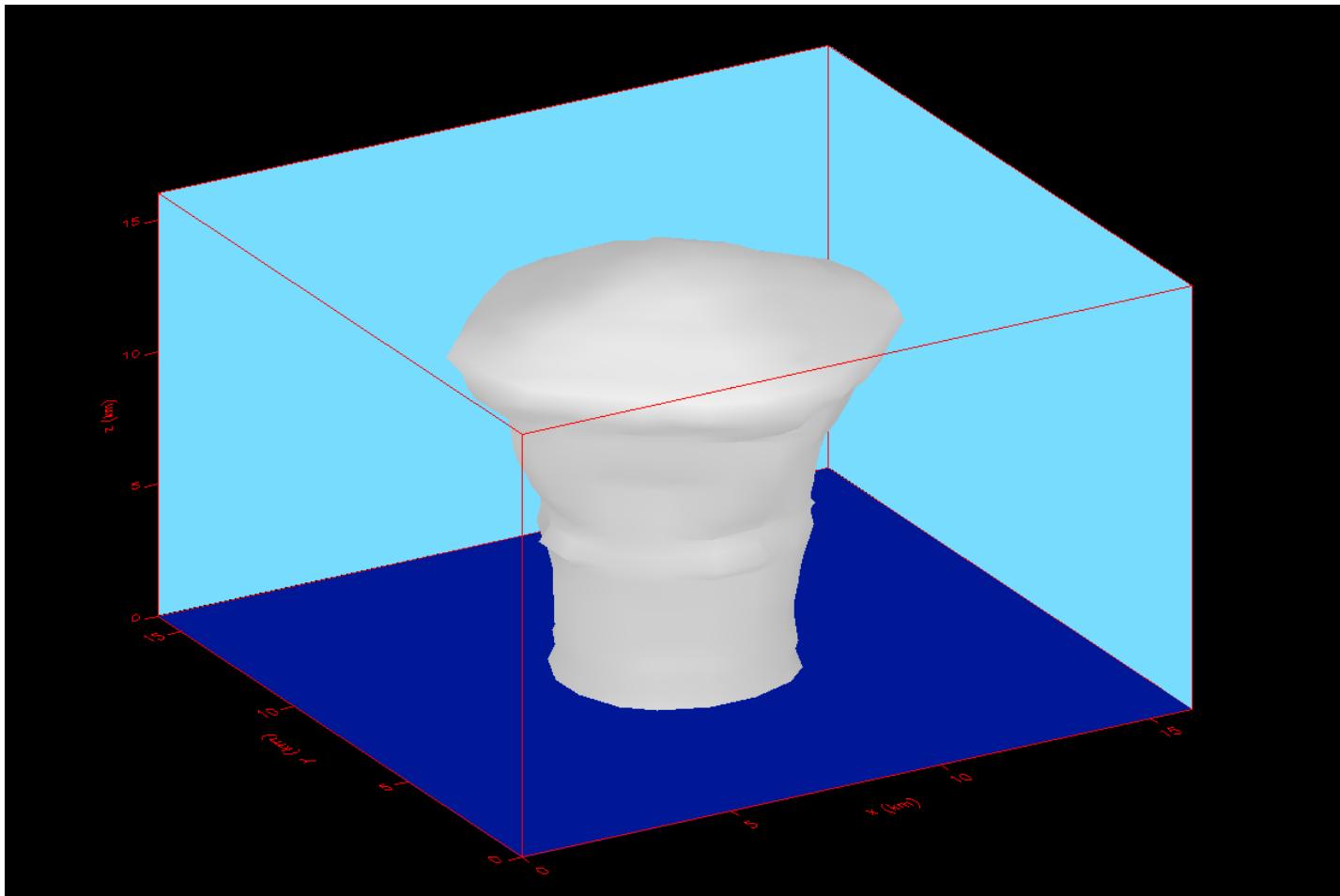
NASA



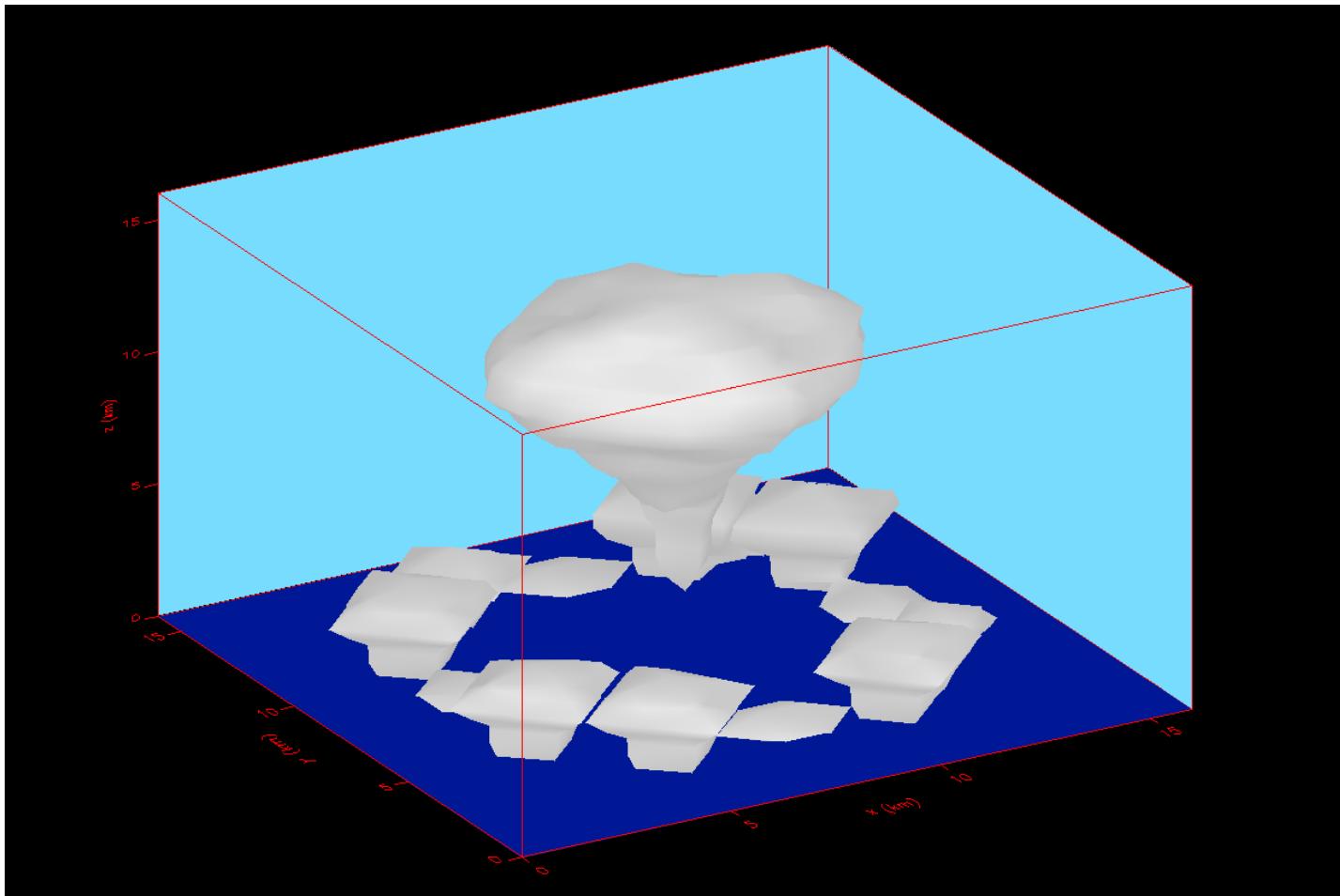
# Iso Animation Backup



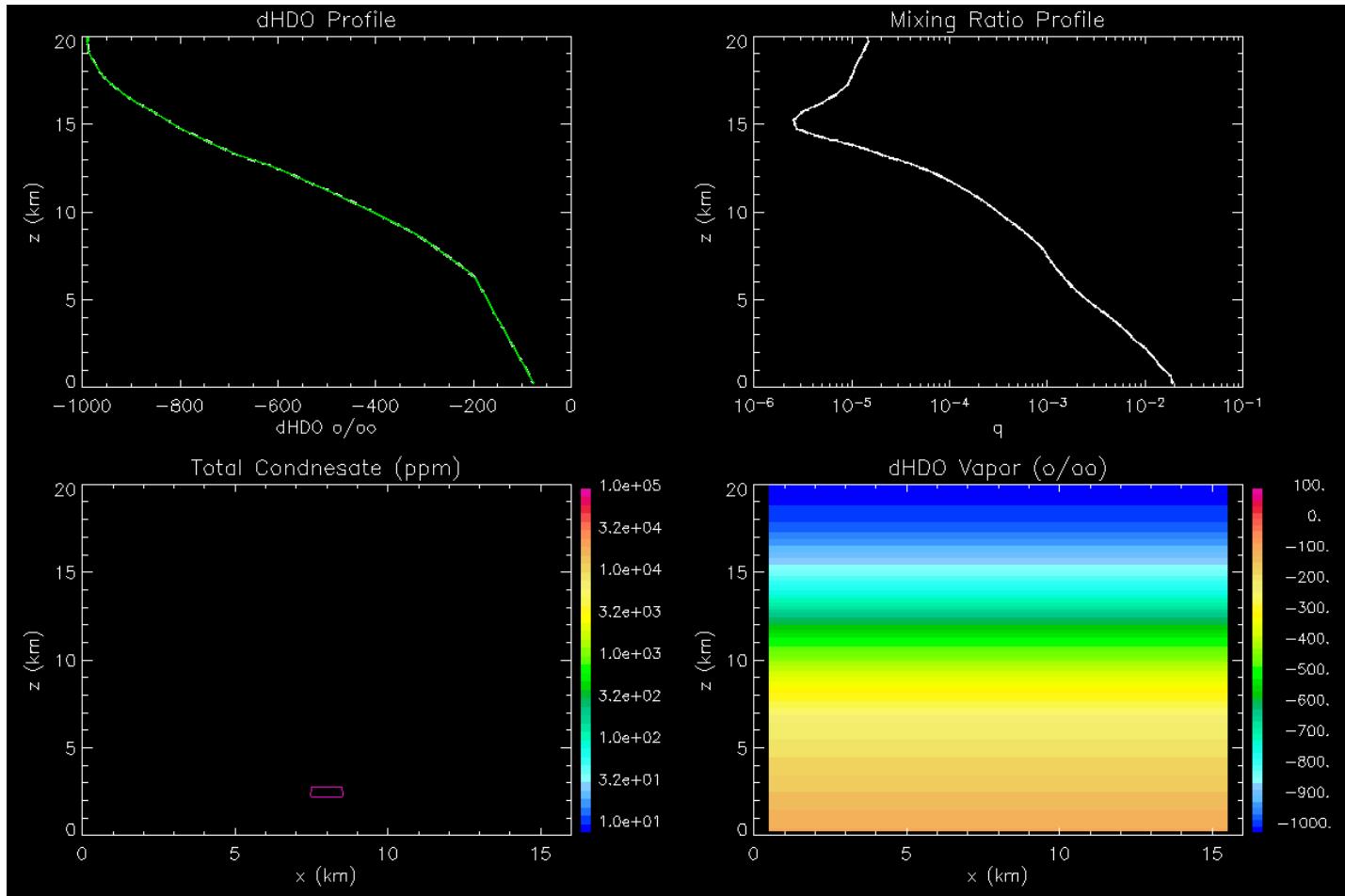
# Iso Animation Backup



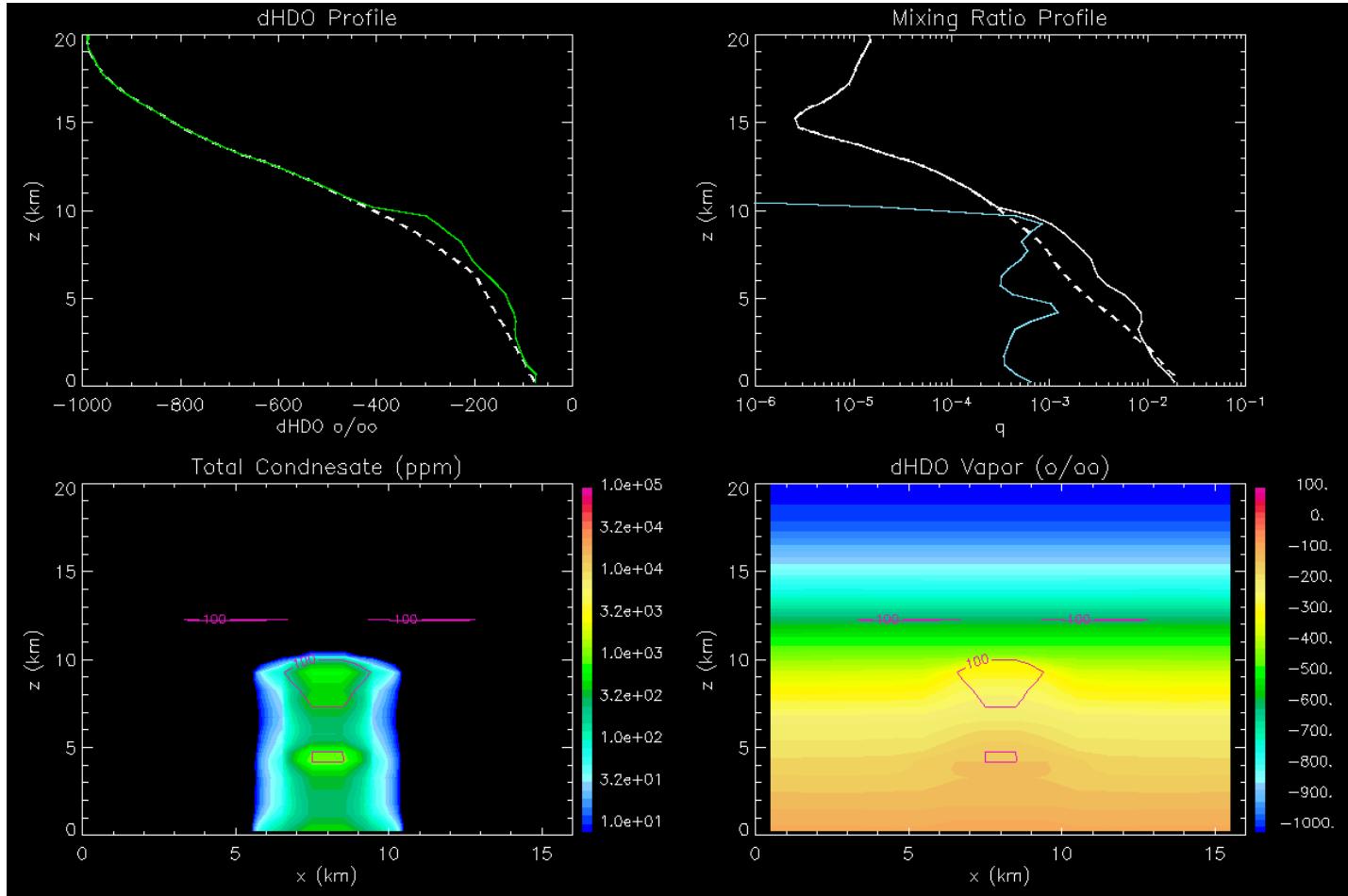
# Iso Animation Backup



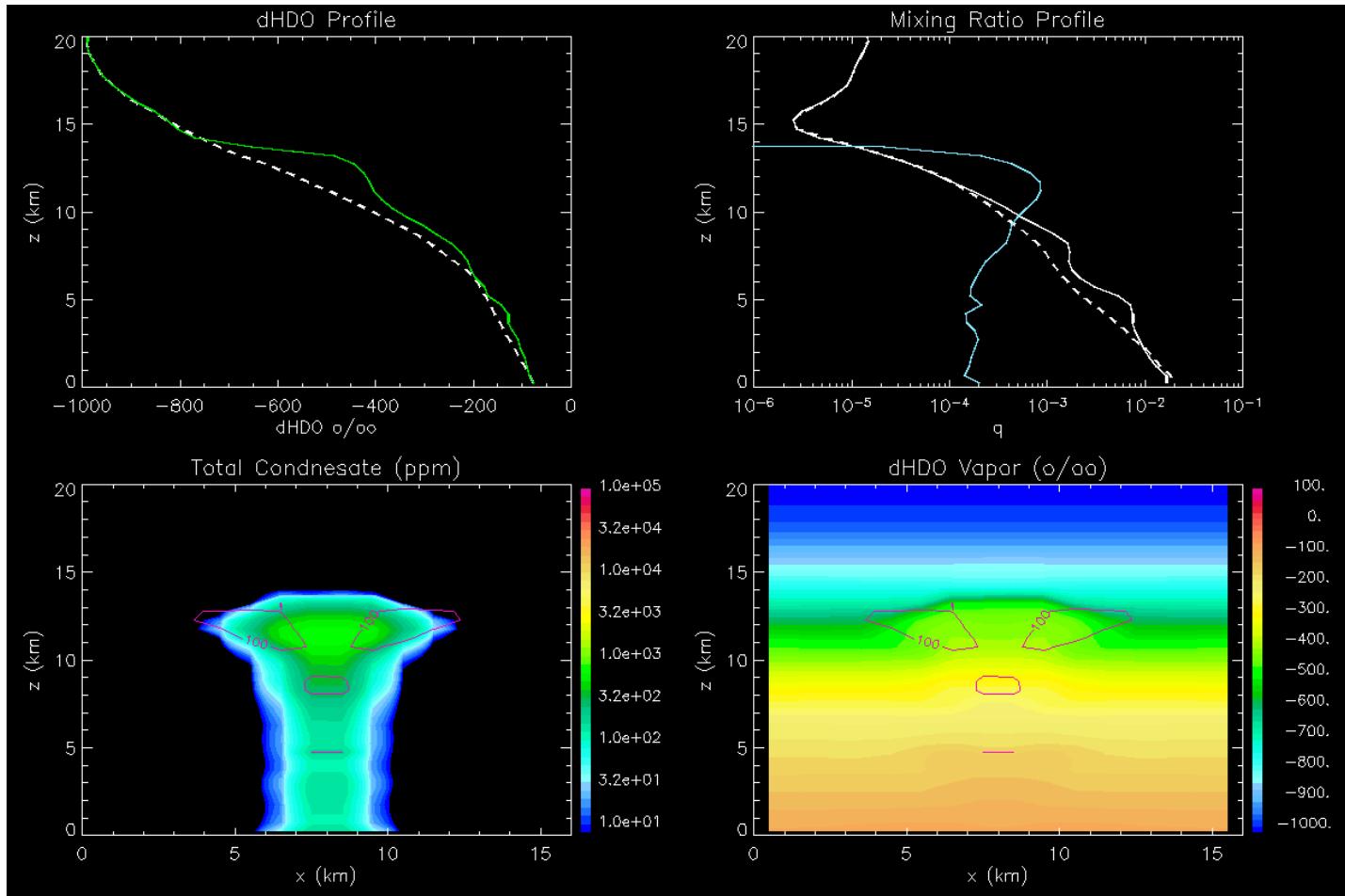
# Slice Backup

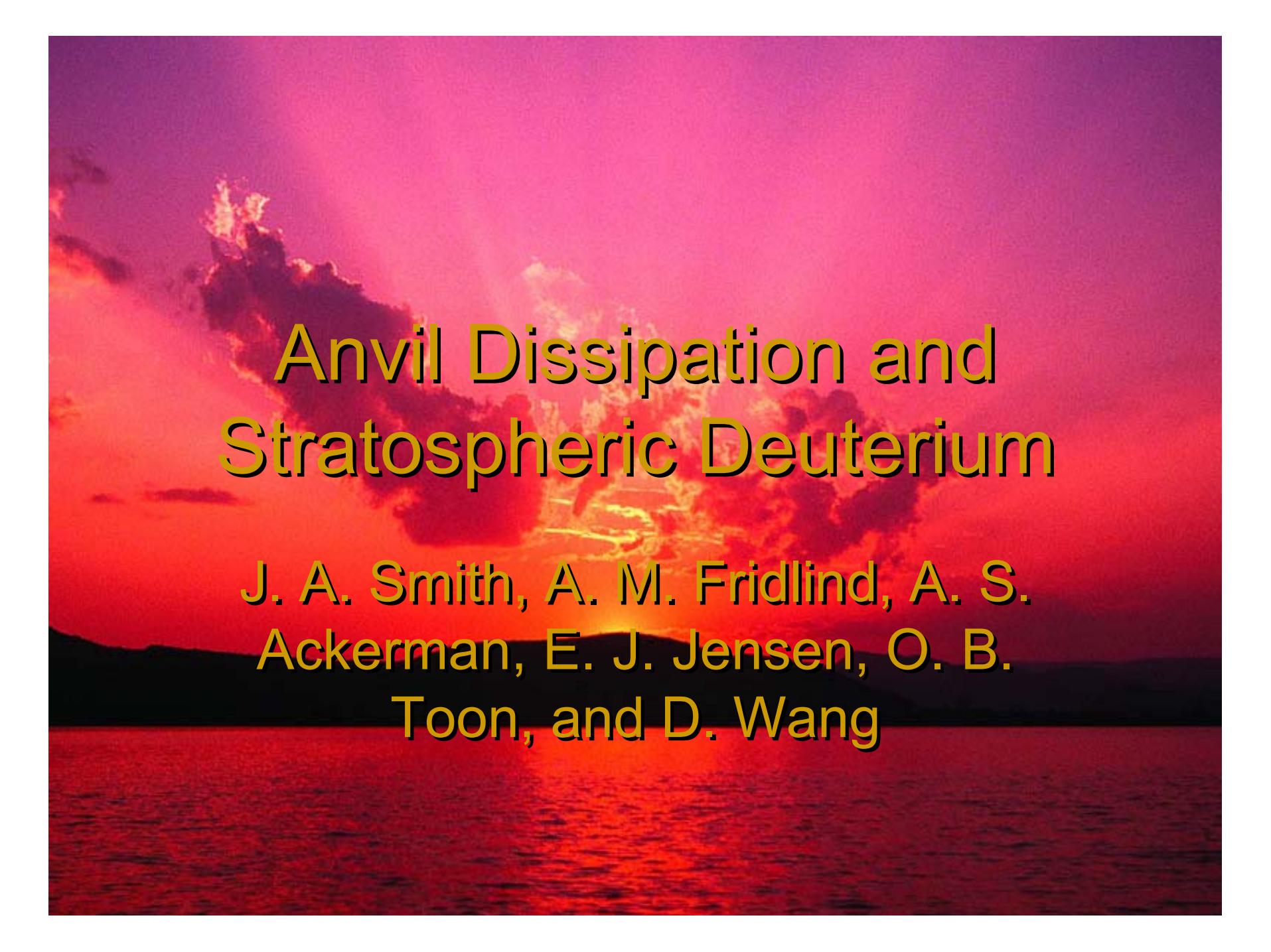


# Slice Backup



# Slice Backup





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